SECTION 4. PLAN FORMULATION

4.1 Methodology of Problem Identification. The problems, needs, and opportunities in the study were identified during the General Investigation (GI) feasibility study through meetings with the City of Portland, Bureau of Environmental Services (BES), Multnomah County Drainage District (MCDD), Portland State (PSU), and the US Fish and Wildlife Service. Study efforts were presented and discussed during monthly meetings of the Columbia Slough Watershed Council. The initial GI feasibility study plan emphasized flow augmentation from the Columbia River. When these alternatives did not prove feasible, a meeting with staff from the Corps, BES, MCDD, and PSU identified the additional alternatives which are presented in this report. A Letter of Intent was sent to the Corps by the City of Portland on April 5, 2000, requesting the conversion of the Columbia Slough General Investigation feasibility study to a Section 1135 project. A Preliminary Restoration Plan was submitted by the Portland District for a Section 1135 study on Columbia Slough, and the study was approved for feasibility initiation. The draft Ecosystem Restoration Report and environmental assessment were reviewed by the Corps technical review team and interested Federal, state, and local resource agencies and tribes.

4.2 Alternatives. A total of eight action alternatives were considered in the study. One of these alternatives, the installation of culverts through the main flood control levee at MCDD#4, was dropped from further consideration after initial analyses indicated a cost exceeding $3 million but affecting only 5 acres of habitat. Alternatives are described in the following sections. Their locations are shown on Figure 3a and 3b.

4.2.1 Without Project Conditions. The without project alternative assumed that existing flood protection measures and projects would continue to be operated and maintained. It also assumed projected growth and development in the area would be fully achieved, existing Protection Zones would remain in their current condition, and any legally required mitigation measures and water quality improvement projects would be realized within the planning timeframe. Columbia Slough will remain an ecologically stressed system with fragmented habitat and poor benthic invertebrate species diversity. High levels of macrophytes will continue due to the water level management practices of the Multnomah County Drainage District (MCDD), which are designed to reduce summer algal blooms caused by high nutrient levels.

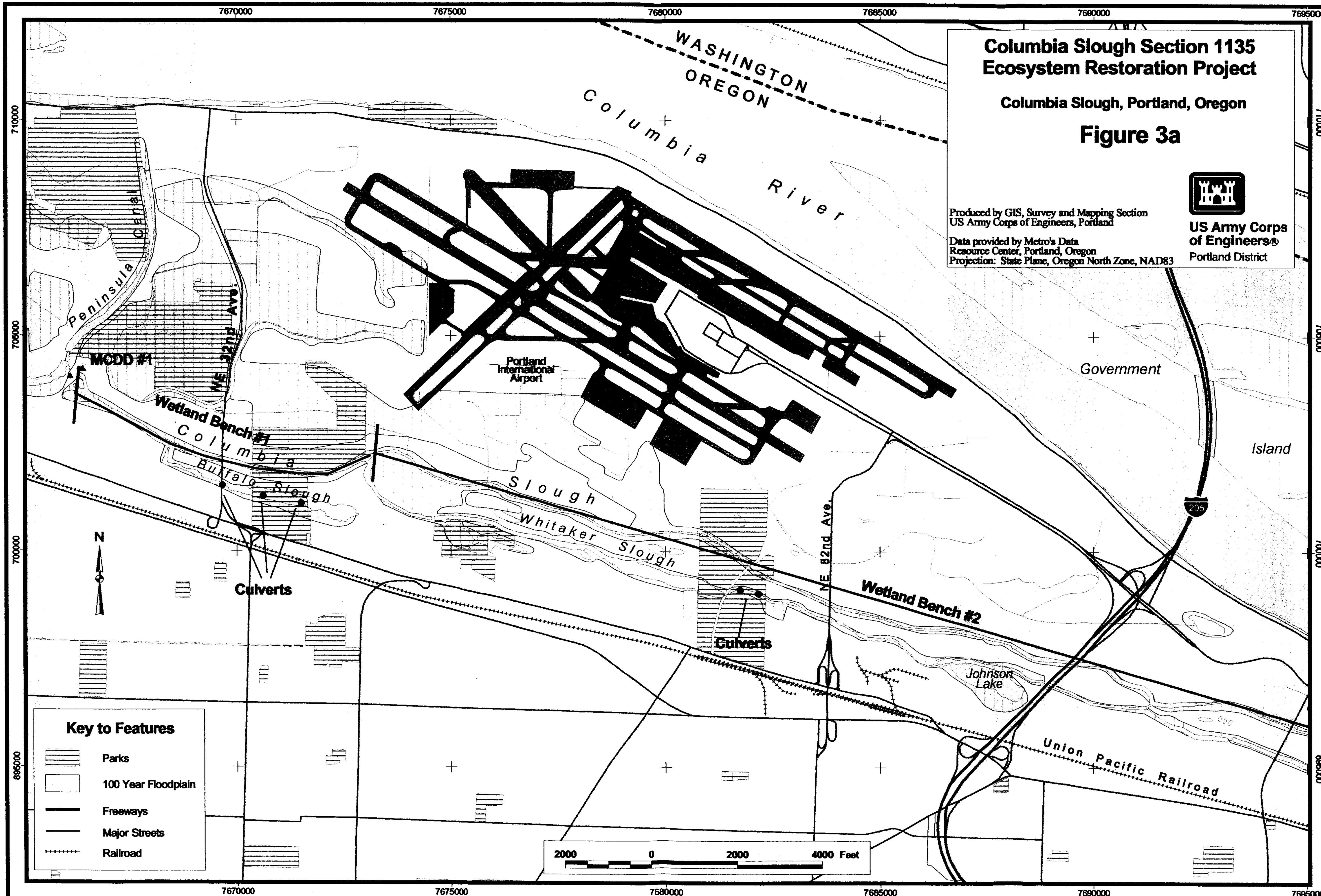
4.2.2 Wetland Benches. - Little emergent marsh habitat is available along the main slough, primarily due to the steep banks and narrow channel along most of the project area. This alternative would involve dredging Columbia Slough from MCDD #1 to NE 158th Avenue (Figures 3a and 3b) to a designed depth and placing the material along the edges of the channel to create wetland benches and a meandering channel during low water summer conditions (Figure 4). The benches would be planted to provide emergent wetland and riparian scrub-shrub wetland vegetation, depending on actual water depth. No real estate costs are associated with this segment, as Multnomah County Drainage District No. 1 has existing flood control maintenance easements which can be used on this project.

4.2 3 Galitzki Springs/Flats. The 19.1-acre site, located east of NE 162nd Avenue between Airport Way to the north and the Union-Pacific Railroad right-of-way to the south (Figure 3b), consists of a 9.4-acre low-lying field (Galitzski Flats; also known as Mason Street wetland) dominated by reed canary grass and a 9.7-acre heavily vegetated sideslope (Galitzki Springs) incised by several small drainages associated with perennial springs. Galitzski Flats was originally a permanent open water body (Duck Lake) that was drained in the early 1920s. Restoration would focus on re-creating wetland and open-water habitat in the Galitzki Flats (Figure 5), and increasing riparian forest cover, improving age-distribution, and snag recruitment in Galitzki Springs. The 9.4-acre Galitzski Flats segment is already owned by the City of Portland. The Galitzski Springs segment is in private ownership.

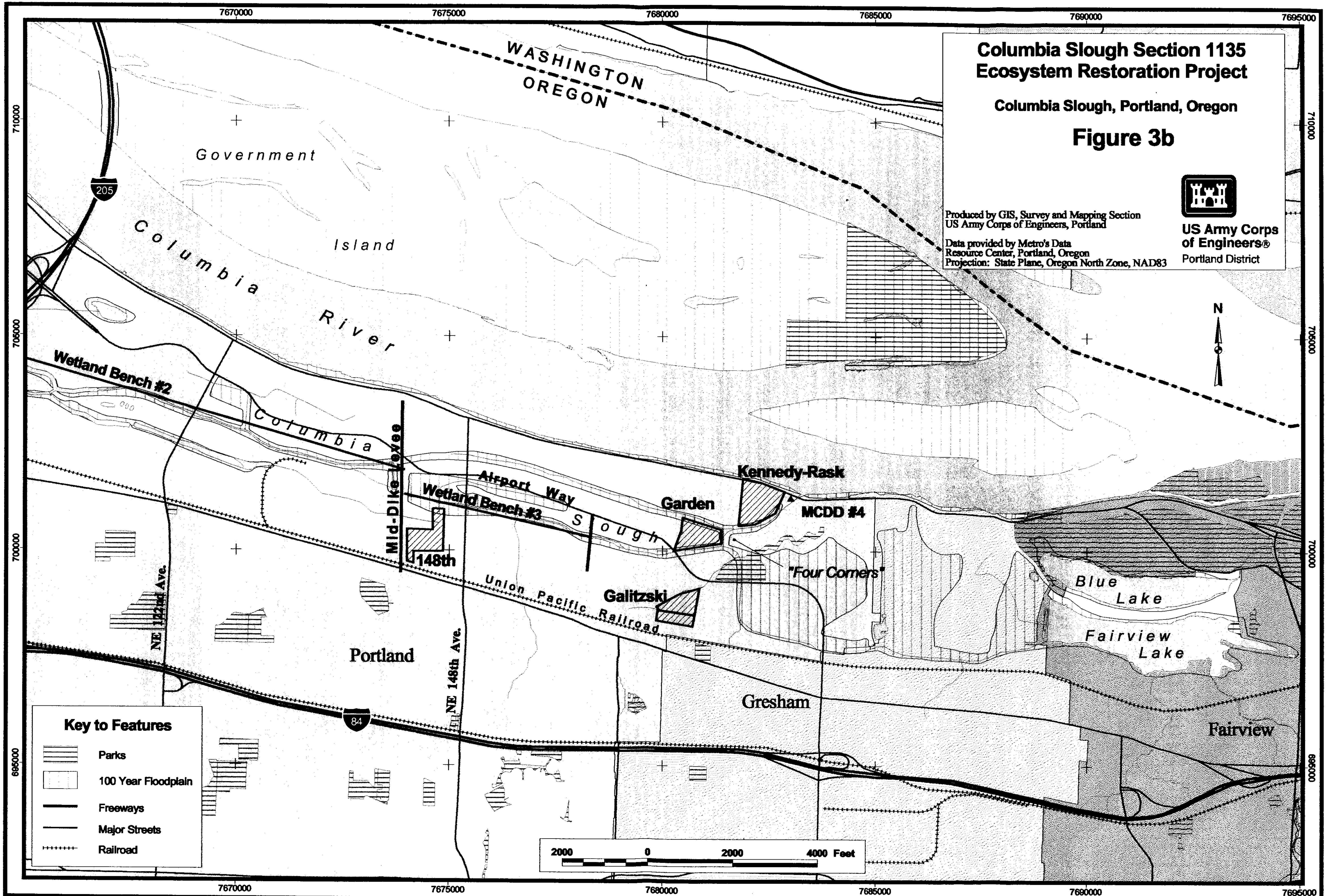
4.2.4 Kennedy/Rask. This 19.7-acre site (Figure 3b) west of MCDD Pump Station #4 includes an open ditch in the west-central portion of the property and an arm of Columbia Slough along the south side. Vegetation consists almost entirely of Himalayan blackberry, with some scattered pockets of black cottonwood, red-osier dogwood, willow, and rose. Restoration would consist of mechanically removing the dense cover of Himalayan blackberry, with the existing cottonwood, willow, rose and dogwood left as undisturbed as possible. Wetland hydrology would be restored to the northern portion by modifying the ditch and associated drainage feature. Native plant species would be planted to re-establish the cottonwood-ash community, and riparian scrub-shrub vegetation would be established in the wettest areas. In addition, a 4-acre section would be planted to provide seasonally wet meadow habitat. This site is in private ownership, and is presently for sale (October 2000).

4.2.5 Gardenburger. The 15.5-acre subject property is located north of Airport Way between NE 162nd and NE 181st Avenues (Figure 3b). Vegetation consists of a mixture of riparian deciduous forest, pine plantation, and dense thickets of Himalayan blackberry. Immediately east of the site is an arm of Columbia Slough, with a contiguous 34-acre stand of cottonwood-ash on the opposite bank. Restoration would entail removing Himalayan blackberry and planting cottonwood-ash forest cover and meadow vegetation. The pine plantation would be thinned to encourage growth of trees and undestory shrubs. Since existing deciduous riparian forest cover is optimal for the management species, it would not require treatment. This site is in private ownership.

4.2.6 NE 148th Avenue Constructed Wetland. Stormwater runoff from 294 acres in the NE 148th Avenue basin (Figure 3b) will reach a constructed wetland through an existing 48-inch storm drain. Runoff will enter a 2.4-acre wet detention pond (forebay) for sediment removal and hazardous material spill containment, then flow into a 3.3-acre constructed wetland marsh. (The 3.3-acre constructed wetland is the alternative considered in this study). Water from the constructed wetland will then flow to an existing wetland and a small pool before entering an existing drainage ditch to Columbia Slough. The constructed wetland will consist of 1.5 acres of low marsh, 1.5 acres of high marsh, and 0.3 acres of semi-wet marsh. Based on the bottom elevation, the vegetation will consist of a combination of submerged and semi-submerged plants and



Columbia Slough Section 1135
Ecosystem Restoration Project
Columbia Slough, Portland, Oregon
Figure 3a
Produced by GIS, Survey and Mapping Section
US Army Corps of Engineers, Portland
Data provided by Metro's Data
Resource Center, Portland, Oregon
Projection: State Plane, Oregon North Zone, NAD83
US Army Corps of Engineers®
Portland District
WASHINGTON
OREGON
Columbia River
Peninsula Canal
MCDD #1
NE 32nd Ave.
Portland International Airport
Government
Island
Wetland Bench #1
Columbia
Buffalo Slough
Slough
Whitaker Slough
Culverts
Culverts
NE 82nd Ave.
Wetland Bench #2
205
Johnson Lake
Union Pacific Railroad
N
Key to Features
Parks
100 Year Floodplain
Freeways
Major Streets
Railroad
2000 0 2000 4000 Feet
7670000
7675000
7680000
7685000
7690000
7695000
710000
705000
700000
695000



Columbia Slough Section 1135
Ecosystem Restoration Project
Columbia Slough, Portland, Oregon
Figure 3b
Produced by GIS, Survey and Mapping Section
US Army Corps of Engineers, Portland
Data provided by Metro's Data
Resource Center, Portland, Oregon
Projection: State Plane, Oregon North Zone, NAD83
US Army Corps of Engineers®
Portland District
WASHINGTON
OREGON
Government
Island
Columbia
River
205
Wetland Bench #2
Columbia
Mid-Dike Levee
Airport Way
Wetland Bench #3
Slough
148th
Kennedy-Rask
Garden
MCDD #4
"Four Corners"
Galitzski
Union Pacific Railroad
Blue
Lake
Fairview
Lake
NE 122nd Ave.
NE 148th Ave.
Portland
Gresham
Fairview
84
N
Key to Features
Parks
100 Year Floodplain
Freeways
Major Streets
Railroad
2000
0
2000
4000 Feet
7670000
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7685000
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700000
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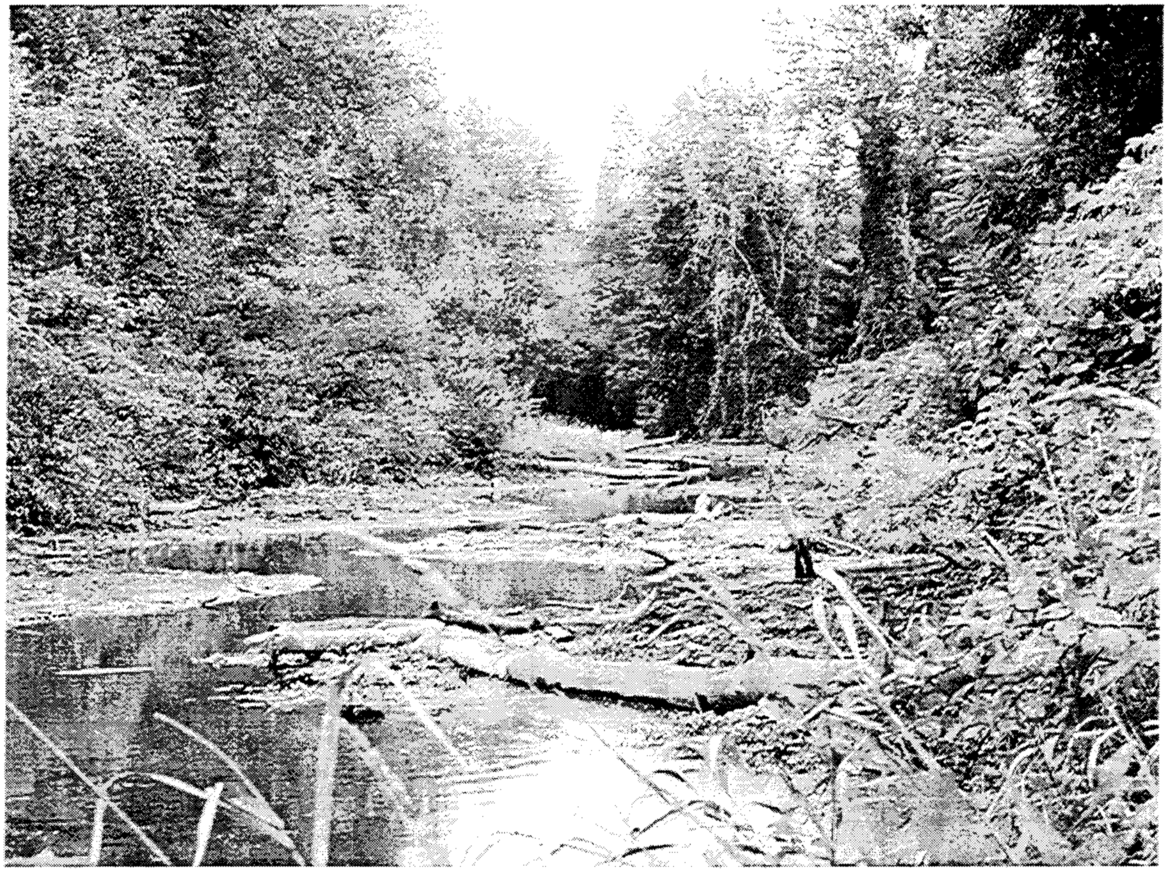

Figure 4. Wetland benches following initial construction, Bridgeton Slough.

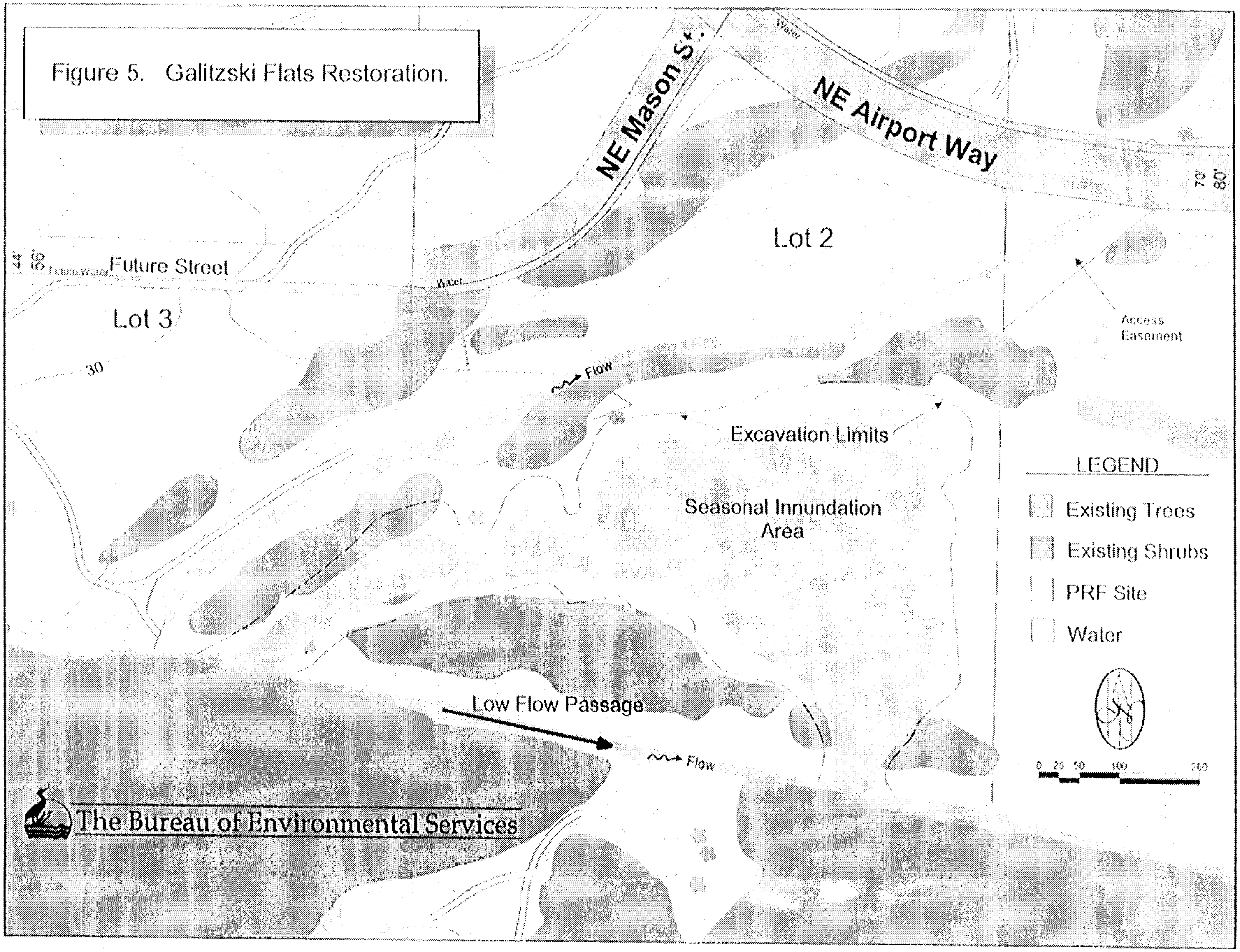

Figure 5. Galitzski Flats Restoration.

vegetation growing in saturated soils. This site has recently been purchased by the City of Portland.

4.2.7 Buffalo Slough Culvert Replacement. Undersized, blocked, deteriorated, and/or high invert elevation culverts are restricting flow in Buffalo Slough and Whitaker Slough (Figure 2a). These flow restrictions increase hydraulic retention time and raise water surface elevations. The stagnant water provides favorable conditions for high water temperatures and severe algal blooms, leading to poor water quality and aesthetics. Culverts will be replaced to decrease water residence time in the slough. Native vegetation will be planted in areas of exposed shoreline to restore wetland vegetation. The primary habitat benefits would be increased benthic invertebrate production and diversity. Each of the culverts would require construction easements.

4.2.8 Whitaker Slough Culvert Replacement. Deteriorated, high invert elevation culverts are also restricting flow in Whitaker Slough (Figure 2a), with similar problems as stated for Buffalo Slough. Culverts will be replaced to decrease water residence time in the slough. Native vegetation will be planted in areas of exposed shoreline to restore wetland vegetation. The primary habitat benefits would be increased benthic invertebrate production and diversity. Both of the culverts would require an easement. The combined effects of replacing the culverts and managing water levels in the main slough will require that the water supply intake for Colwood Golf Course be replaced with a well. This item, with an estimated project cost of $162,000, would be a responsibility of the local sponsor (City of Portland) to replace, but they would receive credit on their cost share. (This item was determined to be needed after completion of the cost-effectiveness analysis, and was not included in the cost estimate for Whitaker Slough culverts. However, this alternative proved to be the most cost-effective of all the alternatives, by a significant margin. Even with the cost of the well included, this result would not change.)

4.2.9 Culverts through Flood Control Levee at MCDD #4. In order to improve dissolved oxygen concentrations in the upper slough, this alternative consists of constructing two 48-in gated culverts through the flood control levee adjacent to MCDD Pump #4 (Figure 2b). This would allow the transfer of water between the Columbia River and the upper slough by gravity flow. The structure would include fish screens, sized so criteria would be met for salmonid fry. Initial investigations of this alternative indicated that there would be an initial cost of $3.2 million, with a maximum of 5 acres that would benefit from the alternative. There would also be high maintenance costs for MCDD for the fish screens, due to the presence of algae and macrophytes in the slough system. After discussions with the City of Portland and MCDD, this alternative was not considered feasible and further study was eliminated.

4.3 Evaluation of Management Measures. The seven action alternatives were evaluated in more detail. Each of the alternatives met all engineering and technical criteria. They also met, to varying degrees, the environmental and social criteria and project goals. Evaluation and selection of a final restoration plan are based on several additional criteria. These criteria include the significance of the resource and project area, local sponsor input and support, reasonableness of project cost, cost-sharing policies, and a cost-effectiveness analysis and an incremental cost evaluation analysis (CEA/ICA).

Since the benefits of restoration projects are not typically measured in monetary terms, a benefit-to-cost ratio is not used to determine project justification, and maximizing net benefits can not be used to optimize project outputs. Cost effectiveness and incremental analysis are tools that can be used to evaluate contributions of various plans when benefits are not identified in monetary terms, but rather in environmental outputs. The

Table 4.1. Buffalo Slough Culverts

Location	Diameter	Length	Invert Elevation East end	Invert Elevation West end	Style	Comments
	in	ft	ft MSL			
Buffalo Slough (W to E)						
NE 33rd Ave.	48	122	5.89	5.12	CMP	Corrosion possible; high invert; capacity
Broadmoor W	48	40	4.92	5.07	CMP	Corrosion; pipe split
Broadmoor E	36	56	6.30	5.78	CMP	Corrosion; high invert; capacity

Notes:
CMP = Corrugated metal pipe
CSP = Concrete sewer pipe

Table 4.2. Whitaker Slough Culverts

Location	Diameter	Length	Invert Elevation East end	Invert Elevation West end	Style	Comments
	in	ft	ft MSL			
Whitaker Slough (W to E)						
Colwood W	48	38	6.13	6.34	CSP	Pipe separated; high invert
Colwood E	48	42	5.63	6.17	CSP	Pipe separated; high invert

Notes:
CMP = Corrugated metal pipe
CSP = Concrete sewer pipe

cost effectiveness portion of the evaluation ensures that least cost alternatives are identified for various levels of environmental output. These are referred to as "efficient alternatives". The subsequent incremental evaluation evaluates changes in costs for increasing levels of environmental output. The results of an incremental evaluation do not result in a discrete decision criteria (such as the plan that maximizes net benefits), but provides a tool to facilitate plan selection.

To complete the cost effectiveness and incremental evaluation quantification of the environmental quality, outputs and conceptual level designs and costs for each plan are required. Section 4.4 outlines the methodology that has been used to quantify environmental outputs. This is followed by a description of project costs in Section 4.5, and the results of the cost effectiveness and incremental evaluation in Section 4.6.

4.4 Restoration Benefits

The feasibility study focuses on translating potential water quality benefits resulting from flow management measures and other ecosystem restoration opportunities into biological outputs. A modification of the U.S. Fish and Wildlife Service's Habitat Evaluation Procedure (HEP) was used to assess existing wildlife values and to model the potential benefits of proposed actions. Briefly, HEP is based on the assumption that habitat for selected wildlife species can be described by a Habitat Suitability Index (HSI). HSI models primarily focus on the measurement of physical habitat variables that are strongly correlated with habitat quality for a given species. The HSI is a rating (0.0 to 1.0) of the suitability of the habitat for a particular species when compared to optimum habitat conditions for the species. The index is multiplied by the area of available habitat to obtain "habitat units" (HUs) for a given species. The total number of habitat units for each species and each alternative is divided by the life of the project to calculate the average annual habitat units (AAHUs).

Four species (yellow warbler, downy woodpecker, black-capped chickadee, and Townsend's vole) and one species assemblage (benthic macroinvertebrates) were chosen to quantify the changes in habitat values that are anticipated to occur with the proposed projects (Table 4.3). These indicators were selected for the following reasons:

- The vertebrate species are of local, state, and/or Federal interest.
- The vertebrate species are closely associated with rare or declining natural communities that have been negatively affected by Corps of Engineers projects.
- Benthic invertebrates are a critical link in aquatic food chains.
- Species composition of benthic communities is a good indicator of water quality.
- HSI models exist or can be easily modified to measure habitat conditions.
- Habitat can be easily measured and monitored.

The yellow warbler is a neotropical migrant that has been identified as a species of management concern by Partners in Flight. Yellow warbler habitat consists of wet areas with abundant shrubs or small trees. The species was selected due to its conservation status and its preference for scrub-shrub wetlands, a vegetation type that has been severely impacted in the project area. The yellow warbler is an appropriate species for habitat restoration projects in urban areas due to its ability to nest successfully in residential areas and relatively small nesting area requirements (approximately 0.3 acre).

The downy woodpecker and black-capped chickadee are insectivorous forest dwellers. These species were selected to represent forested habitats. Tree density, or basal area, is an important factor for downy woodpeckers, as they forage primarily along bark surfaces. Downy woodpeckers were selected to represent habitat conditions in mixed hardwood/ conifer stands. The canopy volume of trees is a more important habitat characteristic for black-capped chickadees than is basal area. Black-capped chickadees are commonly associated with deciduous forest in Oregon and were selected in this study to represent habitat conditions in cottonwood-willow communities. The availability of snags for nesting is an important factor for both downy woodpeckers and black-capped chickadees.

Table 4.3. Cover types and associated species used in habitat evaluations.

Cover Type	Yellow Warbler	Downy Wood-Pecker	Black-Capper Chickadee	Townsend's Vole	Benthic Inverte-Brates
Riparian scrub-shrub	FR				
Cottonwood/Ash			FR		
Emergent Wetland					FR
Aquatic bottom					FR
Mixed Hardwood/Conifer		FR			
Conifer (plantation)		FR			
Meadow				FR	

F = foraging,
R = reproduction

snags for nesting is an important factor for both downy woodpeckers and black-capped chickadees.

Voles and other microtines that use meadow environments provide an important food source for hawks, owls, snakes, and other predatory animals. Meadows also provide insect prey for bats, swallows, and purple martins. Meadows may also provide nesting areas for painted turtles when located near (i.e., within 500 feet) suitable aquatic habitat.

The abundance and diversity of benthic invertebrates was selected to indicate predicted improvements in all permanently flooded areas (i.e., emergent wetlands and aquatic bottom habitats). Macroinvertebrates serve various functions in aquatic ecosystems, particularly as secondary consumers in many food chains and as recyclers of organic matter. They also are important organisms in the diet of many species of wildlife and fish. Benthic invertebrates play a critical role in the diet of young painted turtles and breeding female ducks. The diversity of benthic invertebrates was selected to indicate predicted improvements in the benthos, including all areas permanently or seasonally flooded.

Increases in habitat units for each species were weighted equally in the analysis. Habitat units were estimated at fully developed levels. Table 4.4 summarizes the total increase in habitat units for each of the action alternatives, as well as the annualized average habitat units (AAHU). The AAHU were used in the cost effectiveness and incremental analyses.

4.5 Cost of Each Measure. Preliminary costs were developed for each conceptual alternative and are summarized below (Table 4.5). Real estate costs are gross estimates. It was assumed that real property acquisitions would not alter current zoning on lands adjacent to the proposed alternatives; cost estimates took into account existing environmental and preservation zoning. Planting and construction costs include engineering and design, construction management, and contingency costs.

Table 4.4. Environmental Outputs

		Habitat Units			
Alternatives	Acres	Existing	With Alternative	New	AAHU*
148th Ave. Wetland	3.3	0.0	3.3	3.3	3.1
Gardenburger	15.5	10.1	14.9	4.8	4.1
Buffalo Slough Culverts	16.7	1.1	7.4	6.3	6.1
Galitzki Spring & Flats	19.1	6.7	17.3	10.6	9.7
Wetland Bench	36.5	4.1	18.1	14.0	13.5
Whitaker Slough Culverts	51.7	4.3	18.4	14.1	13.6
Kennedy-Rask	19.7	0.0	16.8	16.8	14.1
TOTAL	162.5	26.3	96.2	69.9	64.2

* Annualized Average Habitat Units

4.6 Cost Effectiveness and Incremental Cost Evaluation

Each of the seven improvements evaluated in this study could be implemented alone, or in combination with the other improvements. These alternatives are considered individually and in combination in the cost-effective and incremental cost analyses. The average annual habitat units listed represent the net increase in output above and beyond the without project condition.

The costs of implementation for the project include all costs associated with the project, such as development costs, real estate costs, and operation and maintenance costs. The project costs are expressed in terms of average annual dollars per average annual environmental output.

Table 4.6 summarizes the net gains in average annual environmental outputs, the average annual costs, and the average annual cost per environmental output for each alternative site.

Table 4.7 displays the cost-effective least-cost sites and/or combinations of sites, listed in ascending order of average annual environmental outputs. Sites (or combinations of sites) that had a higher cost for a given level of environmental outputs were not cost-effective, and were dropped from further consideration.

Table 4.8 summarizes the results of the final incremental cost analysis. Incremental cost analysis is required to address whether the incremental or additional cost of the next level of output is worth it. In environmental studies, the comparison is between dollar incremental costs and non-dollar incremental units of output. The column on the right summarizes the incremental average annual cost per output, identifying potential breakpoints where the next level of output shows a marked increase in costs. For instance, there is a significant breakpoint in incremental average annual cost per output between the combination including Whitaker, Wetland Benches, Kennedy, Buffalo, and Galitzski sites and the next combination, which adds NE 148th Avenue to the previous group. The incremental average annual cost per output is nearly triple that for the previous combination.

Based on the results of the cost effectiveness and incremental costs analyses, the combination including Whitaker, Wetland Benches, Kennedy, Buffalo, and Galitzski sites, looks like the best investment. However, it should be noted that cost effectiveness and incremental cost analyses alone do not result in a unique plan recommendation.

Table 4.5. Preliminary Cost Summary of Alternatives

Alternatives	Real Estate Cost ($1,000)	Planting & Construction Costs(1) ($1,000)	Subtotal Initial Cost ($1,000)	IDC(2) ($1,000)	Total Project Cost ($1,000)	Average Annual Cost (3) ($)
NE 148th Ave.Wetland	742.5	399.3	1141.8	37.4	1179.2	$ 82,594
Gardenburger	1500	121.3	1621.3	53.1	1674.4	$116,104
Buffalo Slough Culverts	*7.5*	*618.5*	*626.0*	20.5	646.5	$ 44,637
Galitzski Flats / Springs	*505*	*829.0*	*1334.0*	43.7	1377.7	$ 96,964
Wetland Benches	*0*	*777.3*	*777.3*	25.5	802.8	$ 55,429
Whitaker Slough Culverts	*5*	*172.1*	*177.1*	5.8	182.9	$ 12,629
Kennedy-Rask	*1150*	*243.4*	*1393.4*	45.7	1439.1	$100,301

(1) Includes design, construction management,and contingency costs
(2) Interest During Construction
(3) Includes estimated operation and maintenance costs

Table 4.6. Average Annual Environmental Outputs, Average Annual Costs, and Average Annual Cost Per Environmental Output				
Alternatives	**Symbol**	**Ave. Ann. Output**	**Ave. Ann. Cost**	**Ave. Ann. Cost per Output**
Base Condition	Base	0	$ -	$ -
NE 148th Ave. Wetland	148	3.1	$ 82,594	$ 26,643
Gardenburger	Gard	4.1	$116,104	$ 28,318
Buffalo Slough Culverts	Buff	6.1	$ 44,637	$ 7,318
Galitzski Flats / Springs	Gal	9.7	$ 96,964	$ 9,996
Wetland Benches	Wet	13.5	$ 55,429	$ 4,106
Whitaker Slough Culverts	Whit	13.6	$ 12,629	$ 929
Kennedy Rask	Kenn	14.1	$100,301	$ 7,114

Table 4.7. Cost-Effective Least-Cost Combinations, Average Annual Environmental Outputs and Average Annual Cost		
Alternatives	**Ave. Ann. Output**	**Ave. Ann. Cost**
Base	0.0	$ -
Whit	13.6	$ 12,629
Whit-Buff	19.7	$ 57,266
Whit-Wet	27.1	$ 68,058
Whit-Buff-Wet	33.2	$112,695
Whit-Buff-Kenn	33.8	$157,567
Whit-Wet-Gal	36.8	$165,022
Whit-Wet-Kenn	41.2	$168,359
Whit-Buff-Wet-Gal	42.9	$209,659
Whit-Buff-Wet-Kenn	47.3	$212,996
Whit-Wet-Kenn-Gal	50.9	$265,323
Whit-Buff-Wet-Kenn-Gal	57.0	$309,960
Whit-Buff-Wet-Kenn-Gal-148	60.1	$392,554
Whit-Buff-Wet-Kenn-Gal-Gard	61.1	$426,064
Whit-Buff-Wet-Kenn-Gal-148-Gard	64.2	$508,658

Table 4.8. Summary of Final Incremental Cost Analysis					
Alternatives	**Total Ave. Annual Cost**	**Total Ave. Annual Output**	**Added Ave. Annual Output**	**Added Ave. Annual Cost**	**Incremental Ave.Ann. Cost / Ave.Ann. Output**
Base	$ -	0.0	0	$ -	$ -
Whit	$ 12,629	13.6	13.6	$ 12,629	$ 929
Whit-Wet	$ 68,058	27.1	13.5	$ 55,429	$ 4,106
Whit-Wet-Kenn	$168,359	41.2	14.1	$100,301	$ 7,114
Whit-Wet-Kenn-Buff	$212,996	47.3	6.1	$ 44,637	$ 7,318
Whit-Wet-Kenn-Buff-Gal	$309,960	57.0	9.7	$ 96,964	$ 9,996
Whit-Wet-Kenn-Buff-Gal-148	$392,554	60.1	3.1	$ 82,594	$ 26,643
Whit-Buff-Wet-Kenn-Gal-148-Gard	$508,658	64.2	4.1	$116,104	$ 28,318

4.7 Justification and Selection of Final Plan. Cost-sharing policies also affect the decision on the recommended plan. The local sponsor's cost share for a Section 1135 project is 25%. The local sponsor is also required to obtain all lands, easements, rights-of-way, utility or public facility relocations, and dredged or excavated material disposal areas (LERRD) required for the implementation, operation and maintenance of the project. The City of Portland wants to include the Galitzski alternative in the recommended plan, as they already own the 9-acre Galitzski Flats site, about half of the real estate for the Galitzski alternative. Inclusion of Kennedy-Rask would include an additional $1.1 million cost in real estate acquisition for the city. Although the Kennedy-Rask site has reasonable environmental outputs, it is not included in the final plan recommended for implementation because of the relatively high financial cost to the City, and because over 80 percent of the cost of this alternative is real estate. The resulting plan includes culvert replacements at Whitaker and Buffalo Sloughs, wetland benches along the main Columbia Slough, and restoration at Galitzski Springs /Flats.